FY-2001 PROPOSED SCOPE OF WORK for: **Project #:** 107

Gunnison River Temperature Model Development and Scenario Testing

Lead Agency: Hydrosphere Resource Consultants, Inc.

Submitted by: John Carron, Ph.D., Principal Investigator
Hydrosphere Resource Consultants, Inc.
1002 Walnut, Suite 200
Boulder, Colorado 80302
Phone: (303) 443-7839
Fax: (303) 442-0616
jcc@hydrosphere.com

Date: March 20, 2000 (Revised May 8, 2000)

Category:	Expected Funding Source:
_ Ongoing project	X Annual funds
_ Ongoing-revised project	_ Capital funds
X Requested new project	_ Other (explain)
_ Unsolicited proposal	

I. Title of Proposal:

Gunnison River Temperature Modeling and Potential Impacts of Modifications to Aspinall Reservoir Operations

II. Relationship to RIPRAP:

Colorado River Action Plan: Gunnison River
I. Provide and Protect Instream Flows
II. Restore Habitat

III. Study Background/Rationale and Hypotheses:

Records indicate that Colorado Pikeminnow historically were found in the Gunnison River as far upstream as the city of Delta (Quarterone, 1993). Basin hydrology has been significantly altered by the construction and operation of the Aspinall Reservoirs (Blue Mesa, Morrow Point and Crystal), and by diversion and return flow features primarily related to irrigation in the areas surrounding Montrose and Delta. Cool stream temperatures resulting from changes to the basin hydrology (Stanford, 1994) have been identified as a significant impediment to re-establishment of pikeminnow habitat in the Gunnison River near Delta (Osmundson, 1999). Results of Osmundson's work indicate that increasing mean water temperatures at Delta by 1 °C in June, September and October, and by 2 °C in July and August, would increase the mean annual thermal units (ATU) from 32 to 46 units. Such an increase would put stream temperatures at Delta at a level similar to sites on the Yampa and Colorado Rivers which have abundant populations of pikeminnow.

Stream temperature in reservoir-regulated rivers is a function of several related variables. The "natural" mean water temperature is closely related to mean ambient air temperature (Sinokrot and Stefan, 1993). Water released from a reservoir will tend to approach this ambient water temperature as it travels downstream. In most large reservoirs, water is released from near the bottom of the dam. In summer months releases will typically be significantly colder than the ambient air temperature. The rate at which the water warms, and the ability to achieve a specific temperature at a specific location, depends on release temperature, flow, and atmospheric conditions. In general, increasing reservoir release temperatures will result in warmer downstream temperatures. However, the relationship between release temperature and downstream temperature is nonlinear (e.g., a 1 °C increase in release temperature does not necessarily result in a 1 °C increase downstream) and is limited by the ambient atmospheric conditions. Reducing reservoir releases (flow) will also increase downstream temperatures. This is the result of a reduced heat capacity per unit surface area of stream, and of the slower rate at which the water travels downstream, thus increasing the time it is exposed to atmospheric heating.

There are essentially two ways that downstream temperature modifications can be achieved in the Gunnison River. It is necessary to increase the temperature of the water being released from the Aspinall Reservoirs, and/or to decrease the amount of water being released. Analysis of the potential for releasing warmer water is complicated by the physical character of the Aspinall system. It is not immediately clear which reservoir or reservoirs would need to be modified with selective withdrawal structures. Warmer releases from Blue Mesa does not necessarily guarantee warmer releases from Crystal. A comprehensive physical model of all three reservoirs is required to answer this question.

Funding of this study will provide an assessment of existing conditions in the Basin, enable field work for collection of additional data, and provide for the development of simulation models to determine the feasibility of increasing stream temperatures in the lower Gunnison through use of both flow modifications and selective withdrawal structures on the Aspinall Units. Previous work on the Green River below Flaming Gorge Dam indicate that flow and temperature modifications to reservoir operations can be used to meet downstream target temperatures (Carron and Rajaram, 1999; Carron, 2000).

IV. Study Goals, Objectives, End Product:

The objective of this study is to determine the feasibility of increasing stream temperatures in the Gunnison River near Delta, Colorado through both structural and operational modifications to the Aspinall Reservoirs. We will approach this objective through a two-step process. The first phase of the work, to be completed in FY2001 will involve collection and assessment of existing data from the Gunnison Basin. The data assessment will help us develop an understanding of the physical characteristics of the study area. As part of the data assessment process, we will attempt to identify any previous modeling efforts in either the reservoirs or river reaches of interest. It may be possible to incorporate existing models and / or modeling results into any future modeling efforts we undertake. Results from the data assessment will be available in early 2001. The results will help us identify additional data collection that will be required for future model development. In May or June of 2001, we will begin field work to collect additional data as identified in the data assessment phase.

We will monitor hydrologic conditions in the Basin throughout the summer of 2001, corresponding to the critical periods for increasing stream temperatures at Delta (June – October). Once we have finished data collection, we should be able to make an initial judgement regarding the prospects for increasing stream temperatures at Delta. This judgement will be largely qualitative, although some simple statistical analysis may be useful. The deliverables at the end of FY2001 will include:

> Assessment of existing data and models from the Gunnison Basin, including stream and reservoir temperatures, mainstem and tributary inflows, meteorologic data, and any models of the reservoir / river system.
>
> Work plan outlining additional data collection and field work required to have a "complete" database for future modeling efforts.
>
> An analysis of non-physical factors which may influence temperature control, such as constraints on reservoir operations or water delivery obligations.
>
> An initial assessment of the prospects for obtaining warmer stream temperatures at Delta and what methods are likely to be most effective (e.g., modification of reservoir release hydrograph vs. use of selective withdrawal for releasing warmer water).

Our program goal for the following year (FY2002) will be to develop reservoir temperature models using CE-QUAL-W2, and a stream temperature model of the Gunnison River below Crystal Reservoir using the same model developed previously for the Green River below Flaming Gorge (Carron, 2000). The models will be used to gain a more complete quantitative understanding of the impacts of modified reservoir operations. The models will address the following questions:

> Would selective withdrawal capabilities on one or more of the Aspinall Reservoirs result in an increase in release temperature from Crystal Dam?
>
> Would an increase in release temperatures from Crystal Dam result in a significant increase in stream temperatures in the area around Delta, Colorado?
>
> If so, how much warmer would the release waters need to be to meet the targets identified in Osmundson's 1999 report?
>
> What impact does flow have on stream temperatures at Delta, and what flow modifications at Crystal Dam would be necessary to increase stream temperatures at Delta?
>
> What are impacts of reservoir modifications on other locations in the river (e.g., what happens to temperatures in the Black Canyon, where a trout fishery exists)?

V. Study Area:

The study area includes the Gunnison River and its tributaries from Blue Mesa Reservoir downstream to its confluence with the Colorado River.

VI. Study Methods/Approach:

The study will be broken down into a set of sequential objectives. These objectives include identification and collection of required data, assessment of data and operational /institutional constraints, model development and calibration, scenario simulation, and study documentation and a final report.

Data Collection and Field Work [FY2001]. Temperature data are available for various sites within the Gunnison and for release temperatures from the Aspinall reservoirs. Additional existing data will be obtained from various gage, diversion, and reservoir sites, and meteorological data from local met stations. Field work may be necessary if the existing data are insufficient for purposes of this assessment. The scope of any field work will likely involve stream temperature and/or flow monitoring of significant tributary inflows such as the North Fork of the Gunnison or the Uncompahgre River, and additional collection of meteorological data in remote sections of the river corridor (e.g., Black Canyon).

Data Assessment and Temperature Control Issues [FY2001]. Analysis of the data will provide insight as to the potential for stream temperature control through operational modifications to the Aspinall Reservoirs. Examination of key data such as mean daily air temperature, mean stream temperature, and reservoir temperature profiles, we should be able to evaluate the prospects for achieving warmer stream temperatures. The assessment will be considered within the context of existing operational and institutional constraints which will influence controllability.

Model Development and Calibration [FY2002]. Temperature models of the Aspinall Units will be developed using CE-QUAL-W2. The models will allow us to simulate different scenarios involving the addition of selective withdrawal structures to one or more of the Aspinall reservoirs. Results from this modeling effort will indicate the feasibility of obtaining warmer release temperatures from Crystal Reservoir. A flow and temperature model of the Gunnison River will also be developed. This model will be capable of predicting daily mean stream temperatures at a number of locations downstream of Crystal Reservoir. Similar models based on reservoir release temperatures, flow, channel characteristics, and atmospheric conditions have been developed for the Green River below Flaming Gorge Dam, and for the Stanislaus River in California (Carron, 2000). While the ability to obtain higher stream temperatures would be enhanced by warmer release temperatures, it is possible in many cases to meet stream temperature goals through the use of modified flows alone. Thus results from the reservoir model should not necessarily preclude the development of a stream temperature model.

Scenario Simulations [FY2002]. A number of model scenarios will be developed. The scenarios will take into account various operational and physical constraints such as minimum instream flows, limitations on selective withdrawal structures, etc. Results will provide the Recovery Program with a set of guidelines from which flow and release temperature recommendations can be made, and will indicate the usefulness of potential reservoir outlet structure modifications.

VII. Task Description and Schedule:

1) Existing Data Collection. Identify and gather currently available data including Gunnison River flows, tributary inflows, reservoir releases, stream and reservoir temperatures, and meteorological station weather data. Completion Date: April 2001.

2) Field Work. Based on (1), field work may be necessary to collect additional. Because summer and early fall are the critical periods of interest, field work will not be completed until October 2001.

3) Operational and Institutional Constraints. There may be non-physical factors which limit stream temperature controllability. These may include operational constraints on the Aspinall Reservoirs (e.g., flood control, recreation) and releases for downstream water interests. We will identify these factors and provide an analysis of their impacts on proposed modifications to the Aspinall system. October 2001.

4) Data Analysis and Assessment. A qualitative examination of the data from (1) – (3) can help identify possible impediments (both physical and institutional) to controlling stream temperatures. This assessment will provide the Recovery Program with an analysis of current system conditions, and explore the feasibility of using flow and/or release temperature modifications to achieve warmer stream temperatures at Delta. Completion Date: preliminary (Sept 2001); final (following completion of field work, December 2001). *Assuming the prospects for controlling temperatures are good, we anticipate proceeding with a modeling effort in FY2002. It is anticipated that the following tasks would be included in this additional work:

5) Reservoir Temperature Model Development and Calibration. The models can be developed once we have completed any necessary field work Calibration of the models is dependent on inflow, meteorological, and water temperature data. April 2002.

6) Gunnison River Temperature Model. Again, this task can be initiated relatively quickly once we have completed the data collection phase. April 2002.

7) Scenario Simulation and Reporting. A set of scenarios will be developed to simulate results of various proposed modifications to the Aspinall Reservoirs. The model runswill be executed during the spring and summer of 2002. A final report and model software will be completed by the end of FY2002 (September).

VIII. Deliverables/Due Dates:

1) April 1, 2001. Technical memorandum detailing data collection and anticipated summer 2001 field work.

2) October 2001. Technical memorandum detailing summer field work

3) December 2001. Final Report: Synthesis of data collection, field work, and institutional setting, and their impacts on controlling stream temperatures. Analysis of existing models, as needed.

4) April 2002. Technical memorandum: Reservoir and river temperature model development and calibration.

5) September 2002. Final Report: Analysis of scenario simulations, delivery of models to Recovery Program.

Budget FY2001:

Labor:	$26,000
Travel:	$2,000
Equipment:	$2,000
Total	$30,000

Budget FY 2002 (ESTIMATED; CONTINGENT ON RESULTS FROM FY2001):

Labor:	$ 50,000 - $85,000
Travel:	$ 2,000
Equipment:	$ 0 - $ 3,000
Total	$ 52,000 – $90,000

Total for Project:
$ 82,000 – 120,000

X. Reviewers:

G. Smith, L. Crist, D. Osmundson, S. Brayton

XI. References:

Carron, J.C. and H. Rajaram. 1999. Impact of Variable Reservoir Releases on Management of Downstream Water Temperatures. Water Resources Research (in review).

Carron, J.C. 2000. Simulation and Optimization of Unsteady Flows and Stream Temperatures in Reservoir-Regulated Rivers. Ph.D. Thesis, Department of Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder.

Osmundson, D.B. 1999. Longitudinal Variation in Fish Community Structure and Water Temperature in the Upper Colorado River. Final Report, Recovery Action Plan, Project # 48-A. U.S. Fish and Wildlife Service.

Railsback, S. 1997. Design Guidance for Short-Term Control of Flow Releases for Temperature Management. Final Report, Pacific Gas and Electric.

Stanford, J.A. 1994. Instream Flows to Assist the Recovery of Endangered Fishes of the Upper Colorado River Basin. U.S. Fish and Wildlife Service, Biological Report #24.

Quarterone, F. 1993. Historical Accounts of Upper Colorado River Basin Endangered Fish. Final Report. Colorado Division of Wildlife, Denver.

Sinokrot, B.A. and H.G. Stefan. 1993. Stream Temperature Dynamics: Measurement and Modeling. Water Resources Research, 29(7), 2299-2312.

Statement of Qualifications

Upper Colorado River Endangered Fish Recovery Program Proposal:

Gunnison River Temperature Data Assessment and Model Development

John Carron, Ph.D.
Dr. Carron has 10 years of academic and professional experience in water resources engineering, simulation and optimization modeling, reservoir operations, and geographic information systems. He has degrees in Water Resources Engineering, Mathematics, and Geographic Information Systems. He recently completed simulation and optimization models of stream temperatures in the Green River below Flaming Gorge Dam. Results of that study are being incorporated into operational guidelines being developed by the Flaming Gorge Operations Workgroup as part of the Colorado Pikeminnow recovery effort in the Green River near Dinosaur National Monument. He has also been involved with developing various reservoir temperature models for the Tennessee Valley Authority, and for Shasta Reservoir in California. Dr. Carron also has experience conducting stream temperature and stream flow studies, and in the use of field data to develop and calibrate temperature models of hydrologically complex river systems.

Jean Marie Boyer, Ph.D., PE.

Dr. Boyer has over 14 years of experience in the areas of water-quality and water resources planning and management. She has degrees in chemical engineering and environmental engineering, specializing in the field of surface water-quality modeling. As part of her Ph.D. dissertation, Dr. Boyer developed a one-dimensional reservoir temperature model using a Lagrangian approach and object-oriented programming techniques. Her publications include over 15 papers which have been published in refereed journals and in conference proceedings.
Dr. Boyer has written several water-quality computer models. In addition, she has used and modified existing models, many of which have been developed by or for federal agencies (e.g., CE-QUAL-R1, CE-QUAL-W2, BETTER, QUAL2E, and WASP5). Her experience includes the simulation of a variety of constituents including temperature, nutrients, dissolved oxygen, toxic substances, and pathogenic microorganisms in lakes, reservoirs, and streams. Reservoir systems Dr. Boyer has simulated include Standley Lake (CO), Aurora Reservoir (CO), Shasta Reservoir (CA), and Flaming Gorge Reservoir (WY/UT).